Integrated environmental monitoring

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ADDENDUM

p. 30, last paragraph:

Reform of conventional economic practices has been promoted by a number of economists. Barbier (1987) has outlined specific reforms in four areas; 'cost-benefit analysis', 'resource accounting', 'macro-economic policy making' and 'sustainability-applied research' that would ...

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CHAPTER 1

Introduction

Monitoring has traditionally taken place along single disciplinary lines despite the fact that it is basic to the management of resources - a process that can never rely on one discipline. This single discipline monitoring has resulted in the inability to predict severe environmental problems, such as forest damage in central Europe from air pollution. A comprehensive understanding of the way in which elements of the environment interact requires an integrated approach to environmental monitoring rather than just physical, chemical, biological or socio-economic aspects.

In this paper, three questions related to integrated environmental monitoring are discussed:

(a) What are the requirements for integrated monitoring?

In Chapter 2 integrated monitoring is defined, reasons why it does not commonly occur are explored and some examples are provided. The role of long-term ecological research and monitoring are discussed. The focus is on the role of the regions and the problems of regional monitoring. The chapter concludes with the necessary requirements if integrated monitoring is to occur.

(b) How can we use integrated monitoring to predict major environmental problems in the future?

In this chapter the role of predictive monitoring is discussed and four approaches are suggested: long-term ecological monitoring, the use of models, the mass balance approach, and change in capacity. The chapter concludes with a discussion of early warning indicators and provides some examples.

(c) What is traditional Maori monitoring and how might Maori monitoring practices be incorporated into a national or regional monitoring system?

In this chapter traditional Maori monitoring practices are discussed along with their origin. This is followed by a discussion of current environmental monitoring and problems encountered. The chapter concludes with recommendations for incorporating aspects of traditional monitoring into a national or regional monitoring system.

CHAPTER 2

Integrated monitoring - what is it?

Izrael and Munn (1986) define integrated monitoring as:

> *"The repeated measurement of a range of related environmental variables and indicators in the living and non-living compartments of the environment, for the purpose of studying large parts of the biosphere as a single system"* (p.361).

Ideally, a system of indicators needs to be developed that reflects the state and management of resources in relation to the long-term goal of sustainability. In order to focus on sustainability there is a need to take a more holistic approach to environmental problems. Biophysical and socio-cultural considerations must be integrated as closely as possible (Baines *et al.*, 1988).

One reason why integrated monitoring has not occurred is that traditional methods of environmental management are not well equipped to adopt this holistic approach. Existing legislation in many countries tends to focus on one environmental medium at a time, for example, the original Clean Air Act in the United States (State of Washington Department of Ecology and U.S. Environmental Protection Agency 1990) and the Mining Act 1971 in New Zealand.

In New Zealand, one of the objectives of the Resource Management Bill (1989) is to:

> *"integrate the laws relating to resource management .... by bringing together the management of land, ... water and soil, minerals and energy resources, the coast, air and pollution control, including noise control"* (p.i).

Another reason for the lack of an integrated approach, related to the first, is that before local government was restructured, each organisation such as catchment boards, harbour boards etc. had its own monitoring agenda and there were few formal mechanisms to ensure useful interactions and exchange with other local bodies. Much depended upon co-operation between individuals. Some formal interorganisational monitoring was conducted under the mandate of the Regional Planning Scheme by some united councils and specific monitoring reports were issued. However, too narrow an interpretation of available powers meant that this process was *ad hoc* and not uniform throughout New Zealand (C.C. Kissling, Lincoln University, pers. comm.).

Despite efforts to restructure and better clarify functions with the formation of regional councils, monitoring carried out prior to restructuring has continued on an *ad hoc* basis to a large extent. Information bases are often structured without consideration of how the data might be used in the future. Managers' attitudes are influenced by the role of their organisational section without consideration of the data collected by others.

An integrated monitoring system needs to be designed and established; it will not just happen or occur naturally or be universally applied. Individuals tend to resist the integration of their single discipline monitoring procedures. They find it is difficult, even annoying, if the benefits are not made clear to them.

> *"Integration requires the conscious and systematic consideration of the many diverse elements of a resource management issue in seeking optimal solutions. [It] requires the development of policies that are preventative and anticipatory as well as reactive"* (OECD, 1989, p.10).

In designing an integrated monitoring system, or modifying an existing system, Izrael and Munn (1986) list the points that need to be considered:

- the objectives of monitoring,
- the time and space resolutions required,
- the accuracy of the answers required,
- the measurement errors (random or biased),
- the space variability of the field and the strength of space correlations (problems of patchiness of ecosystems),
- the time variabilities in the data,
- the practical constraints,
- flexibility of design to allow for changes as the understanding of processes evolves,
- the possibility that a mismatch between program objectives and system capability may occur,

- competing models of the environment could imply different monitoring strategies e.g. the information needed for management depends on whether a stress-response model (see below) or an input-output model (where flows from one sector/location or another are the main variables) is being used,

- the problem of historical monitoring in which the data are fragmentary or impossible to check.

2.1 Examples of integrated monitoring

When dealing with examples of integrated monitoring it is difficult to ignore the socio-cultural and policy aspects since methods used for this type of monitoring by definition involve communication across disciplinary boundaries that may need to be facilitated through the decision-making process. Chapter 4 in this publication looks at some cultural aspects of monitoring in New Zealand.

In the following examples of integrated monitoring there is a range of types of integration from integrated monitoring of the biological, chemical and physical environment, as implied in Izrael and Munn's definition, to integrated monitoring of the biophysical and socio-economic aspects of the environment.

2.1.1 Marine pollution

A straightforward example is given by McRae and Smith (1990) in discussing concentrations of contaminants in the marine environment. Contaminants can be measured in the water column, the sediments and the biota. Their potential effect cannot be appreciated without recognising that these three media form an interlocking system and integration of the data from these media is necessary to obtain a comprehensive picture of marine environmental quality. No single biological indicator will provide all the information necessary to determine the consequences of stress on an ecosystem and a range of indicators from biological, physical and chemical monitoring may be required. For example, indicators in the water column might include nutrients, pathogens, oil and organic wastes. Indicators in the sediments and in invertebrates, fish, birds and mammals might include trace metals and synthetic organic compounds.

An assessment of marine pollution requires both chemical surveys and ecological studies. Chapman and Long (1983) point out that the determination of concentrations of contaminants provides no information on their bio-availability or their potential for adverse effects. For example, many metals are bound to sediments in water so that they are basically inert. Conversely, other compounds such as chlorophenols may be present in relatively small concentrations but may have a large impact on flora and fauna. Chemical analysis of tissues may resolve the problem but some contaminants are metabolised in the organism to compounds that are not usually detected by standard techniques. Also some chemicals accumulate more in certain tissues than in others.

Measuring the ecological community structure alone is not sufficient to determine contaminant effects because the presence or absence of particular species may be due to factors other than pollution e.g. fluctuations in temperature, salinity, dissolved oxygen, sediment texture, water depth or biotic factors such as reproductive cycles, competition or predation. Therefore, a combination and integration of both chemical and ecological studies are required along with additional studies to verify the results i.e. bioassay testing of samples from the field (Chapman and Long, 1983).

2.1.2 Terrestrial ecosystems

Physical, chemical and biological monitoring are also required for an adequate understanding of terrestrial ecosystems. Breymeyer (1981) proposes a network of stations for the integrated monitoring of pine forests in Poland. One station is required in each of the 49 provinces and the sites are to be in protected areas where no changes in management are planned for the next 10 years and the landscape is typical for that part of the country. Breymeyer considers that a minimum programme for monitoring these ecosystems should include:

"1. *Registration of the flow of main contaminants through the vital parts of the ecosystem. For example, in a pine forest ecosystem sulphur and heavy metals are investigated in the needles, lichens, litter, upper soil level and earthworm bodies.*

2. *Measurements of production and destruction of organic matter by standard comparable methods. For example, in a pine forest the organic fall, growth of timber and rate of decay of litter are measured.*

3. *A sufficient description of the soil and plant cover to permit the ecosystem under study to be related to larger scale biogeophysical classifications*" (p.182).

The results would allow a comparison of forest ecosystem functioning across the country and provide a basis for rational management.

2.1.3 Land, water and air

The National Swedish Environmental Monitoring Programme is designed to monitor long-term changes in the environment, to record environmental conditions in background regions that are relatively unaffected by pollution and other disturbances, and to quantify the flux of pollutants in and amongst air, water and land. Integrated monitoring takes place in or near 19 small watersheds throughout the country, usually chosen in national parks or nature reserves. The watersheds represent a variety of climatic, topographic and vegetation conditions. During the selection process, consideration was given to watersheds where research had already been conducted and to those near existing research stations. Co-ordination and integration in the design of a number of projects has involved selected ecosystems where plant and animal studies are combined with analyses of physical and chemical parameters (Bernes *et al.*, 1986).

2.1.4 Wildlife and fisheries

The desire to focus on the social aspects of managing natural systems in addition to the biological and physical resources has resulted in an integrated monitoring system described by Knuth and Neilsen (1989). This system has indicators for wildlife and fishery resource management that include a comprehensive series of biological, environmental, social and institutional dimensions. The dimensions are set out in four management components to form a 16-cell matrix. The components described by Knuth and Neilsen (1989) are:

inputs	raw materials that resource managers have to work with such as land, labour, time and money,
	characteristics of social groups seeking to use the resource base, such as human population densities and current level of demand for wildlife-viewing opportunities,
processes	actions or activities that are normally carried out by wildlife resource professionals,
outputs	direct outcomes of management activities, such as the number of new participants after a youth hunter education course,
impacts	results of output production or consumption, such as reduced user conflicts caused by inexperienced hunters or enhanced perceptions of a management agency.

Resource management performance indicators were identified on the basis of three criteria:

appropriateness	how directly an indicator provides annual information about a given resource element in the matrix,
availability	those indicators found in routinely collected agency data files, accessible government documents, or research literature,

source type	includes agency documents describing indicators in use, reports demonstrating validity or biases of a particular indicator, and reports suggesting a particular indicator may be useful to measure.

Institutional indicators were found to be the most readily available and appropriate of the indicators identified while social indicators were the least available. This lack of social indicators identifies a lack of monitoring capabilities representing the social dimension i.e. people's demand for and use of wildlife resources, compared with the biological and institutional dimensions. It is thought that the "use of the indicator system will lead to more comprehensive and explicit resource management decisions and will help identify promising new areas for research, especially in the human dimension" (p.329).

2.2 Long-term ecological research and monitoring

Long-term ecological research and monitoring inevitably go together and have made great contributions to ecology. Strayer *et al.* (1986) discuss the problems encountered by scientists doing long-term studies, given funding and research institute constraints and the brevity of professional careers. The dedicated guidance of one or a few project leaders is essential, along with clear objectives, simple study design, protection and management of research sites, the choice and measurement of variables, and the collection and management of data. Sutcliffe, Shachak, Lund and others (in Strayer *et al.*, 1986) suggest that a good monitoring programme for long-term studies consists of:

- carefully chosen initial sampling design, variables to be measured, and methodology,
- an interested scientist capable of interpreting the data should examine and process the data as it is collected so that the design of the monitoring programme can be modified as knowledge of the ecosystem increases,
- a flexible monitoring programme so that sampling frequencies or sites, or measured parameters can be changed,
- the core monitoring programme must not be so large that it takes up all the time and resources of the investigator. Time and resources must be available to follow up short-term studies in order to answer questions suggested by the long-term study.

A special programme was set up by the National Science Foundation in the United States to fund long-term studies. It is the Long-Term Ecological Research (LTER) programme. Currently, this programme has 18 sites of representative ecosystem types stretching from the Arctic Tundra in Alaska to the Luquillo experimental forest in Puerto Rico (see Brenneman, 1989). The newest site is the Penguin Centre in Antarctica.

The LTER approach includes objectives to:

- establish an integrated long-term **observational** programme to identify changes,
- undertake research into ecosystem processes to **understand** the systems,
- develop integrative conceptual and **predictive** models.

Core research areas include:

- patterns of primary productivity,
- population dynamics of organisms of various trophic levels,
- pattern and control of organic accumulations in soils and sediments,
- patterns of nutrient flows,
- patterns of disturbance,
- data management.

The LTER sites are located in representative ecosystems in terms of climate, landscape, biota and/or soils. The study areas cover a series of spatial scales from plot/patch to global but most research focuses on the plot/patch and landscape levels (Swanson and Sparks, 1990) and is located in regions of major geographical importance e.g. major river valleys, erosion zones, productive managed plantations.

There is now interest in broadening the disciplines at LTER sites to include, for example, social issues (James T. Callahan, National Science Foundation, pers. comm.).

Long-term ecological research and monitoring are being carried out in New Zealand, for example, the 100 Rivers project, the Craigieburn Range, the

Orongorongo Valley, the Purukohukohu experimental catchment, Lake Taupo and catchments, the Taieri River and many other sites. There is a need, however, for more integration of efforts between and within sites in order to promote the sustainable management of resources and to make ecological research as efficient and effective as possible. Discussion is currently underway in New Zealand to develop an LTER network, along the lines of the U.S. and other national networks. At a workshop held at the Centre for Resource Management, University of Canterbury, for scientists interested in long-term ecological research in November 1990, it was suggested that an LTER network would:

- provide a focus for integrated research and monitoring,
- facilitate comparison of results,
- utilise common skills and technology,
- provide long-term continuity of certain priority research projects,
- offer opportunities for training and education.

A network of LTER sites should be required to serve as focal points for integrating research and monitoring.

A broader type of integrated monitoring occurs in the United States Global Change programme which is not related to LTER but uses the LTER sites. Global change is defined as changes in global climate, bio-diversity, land use and pollutants and involves 25 sites. Four areas have been identified in which global change research is essential: major experiments, modelling and synthesis projects, ecological monitoring, and development of technologies (LTER Network Office, 1989). Items on the Action Plan include to:

- analyse the interactions between land use and global change in which the objectives will be:

- predict the effects of land-use change on key biota and processes at a variety of spatial scales, and
- plan a comprehensive research programme that incorporates modelling, comparative studies, and large scale experiments,

- predict the effects of altered disturbance regimes, such as fires, hurricanes and floods, on ecosystems and their biota,

- establish an integrated programme for environmental monitoring, using existing ecological research sites. This monitoring will include both biotic and abiotic components, multi-agency collaboration, comparable methodology across sites, comparable data management systems, and synthesis and modelling of data.

Monitoring and modelling are thus interdependent, interactive processes (Izrael and Munn, 1986). In the Netherlands, Braat *et al.* (1987) have developed an integrated modelling system for renewable natural resources in Europe, IRENE, which is intended to provide a clearing house for data bases and models of renewable natural resources relevant to Europe. This system would link or integrate biotic and abiotic data along with socio-economic activities and policy issues regarding renewable resources. IRENE aims to answer "what if" questions associated with the analysis of policy options.

2.3 Scale of integrated monitoring in New Zealand

Integrated monitoring in New Zealand can be carried out at a local, regional or national scale.

At the local level, integrated monitoring may be required for land use planning and assessment of environmental impacts. Base-line single discipline monitoring is frequently all that is carried out at this level but in order to assess the impact of development or of a new management regime, an understanding of the ecosystem processes is needed. Information may be required about predator-prey relations or habitat requirements of a particular species, for example. Local scale monitoring would be carried out by local and regional authorities.

At the regional level, integrated monitoring may be carried out for catchment management or forest management, for example. The larger scale may require the selection of key indicators along with base-line data on water, soils and climate that need to be monitored for management of the resource. This level of monitoring would be carried out by regional agencies.

Integrated monitoring at the national scale requires a nationally co-ordinated system with comparable monitoring carried out at the regional level either by a national agency which would collect and process the data centrally or by regional agencies which would process their own data and forward the results to the national centre. Data collected at this scale includes that required by the OECD for global State of the Environment reports and could include data required for a New Zealand State of the Environment report. Careful selection of indicators is required at this level to ensure that key variables, species and processes are being monitored nationally.

2.4 Regional focus

In order to focus on sustainable development, an integrated resource management approach offers the best potential to understand and monitor environmental change. A catchment basis for integrated monitoring would seem to be an appropriate spatial scale and one that has been used in some of the long-term research in New Zealand and in some of the overseas examples given in Section 2.1 such as Breymeyer (1981) and Bernes *et al.* (1986).

At the regional or catchment level the focus can then be on sustainability in terms of sustainable development of both the urban sector and the rural sector. It may be appropriate to look at functional planning regions based on ecological criteria such as climatic and vegetation patterns, soil classification and watershed boundaries (Rees, 1988). The New Zealand ecological districts are described as:

> "*a local part of New Zealand where the topographical, geological, climatic, soil and biological features, including the broad cultural pattern, produce a characteristic landscape and range of biological communities*" (Park *et al.* in McEwen, 1987, p.x).

Although the ecological districts do not conform to institutional boundaries, they allow management to focus on distinct ecosystem types and thus on ecological integrity.

It has been suggested by Rees (1988) that:

> "*Sustainable development requires a proactive planning approach in which ecological integrity is the governing factor and the permissible level of economic activity is the dependent variable*" (p.283).

In terms of sustainable regional development, it may be necessary to obtain explicit acceptance of ecological constraints on human activity and the recognition that humans rather than other elements of the environment are the problem. Successful implementation of such an approach will depend on a shift in the perceptions of society (Rees, 1988).

A regional or ecosystem focus is adopted in the local government and resource management law reforms which give regional government a more prominent role in environmental management (Cocklin and Parker, 1990). The Resource Management Act 1991 allows a closer integration of processes for managing land, water, air and the coast within a framework of policy statements and plans. Regional plans may be prepared by a regional council in the context of a regional policy statement in response to environmental management issues. These plans may be requested by the public and must include the objectives to be achieved, reasons for adopting them, and the environmental results anticipated. Both policy statements and plans may contain environmental standards to be achieved. Monitoring these environmental or performance standards can provide a check on whether the objectives of an authority are being achieved (Ministry for the Environment, 1991).

A comprehensive inventory of environmental resources is needed for each planning region along with a list of human activities that might compromise the quality and/or quantity of those resources. Using a framework as a guide, an environmental monitoring programme can be planned and implemented. Various frameworks have been designed to guide integrated environmental monitoring such as those used in State of the Environment reporting (Ward, 1990).

2.5 Problems of regional monitoring in New Zealand

At present, monitoring at the regional level is carried out by several agencies including regional councils, territorial authorities, Department of Conservation, Area Health Boards, Ministry of Commerce and MAFQual. Central government agencies have their own goals and objectives while regional councils are still at the stage of ad hoc monitoring with few if any formalised monitoring goals and objectives. Much of the monitoring currently carried out is a continuation of some past response to a problem or because the current investigator deems it to be important. The information is collected with little thought as to why it was collected or how it should be used. One variable at a time is often monitored with little or no integration with other data collected. There are also problems of accessing information between and within organisations.

Integration is needed between people as well as integration between methods of data collection.

However, there **have** been some changes in monitoring procedures that reflect a heightened public awareness of environmental trends and issues. For example, when monitoring is undertaken for development projects (such as environmental impact reports), a range of social, economic and natural/physical variables have been increasingly taken into account and inter-relationships noted.

In an informal survey carried out by the Centre for Resource Management in 1989, concern was expressed by central government agencies that monitoring methodologies and policies may not be consistent at the regional level (McRae *et al.*, 1989) i.e. regions may use different methods for data collection and some will place different priorities on carrying out the monitoring, such as the routine measurement of variables related to water quality. The problem in this particular example has been partly overcome by the 100 Rivers programme - a national monitoring programme organised by DSIR. It involves physical, chemical and biological characterisation and modelling of rivers and allows a clearer understanding of what constitutes a "normal" river ecosystem in different regions of New Zealand (Biggs *et al.*, 1990). The programme therefore provides a data base from which significant changes can be assessed. In this project all sampling is carried out by Water Resources Survey field teams using standard sampling techniques.

At present there is no single agency to co-ordinate regional monitoring or to set monitoring standards. A link is needed between regional monitoring activities and a national system of monitoring to **require** regional monitoring by central government agencies at the regional level and by local authorities. A template is required at national level to facilitate this commitment (R.V. Bartlett, Purdue University, pers. comm.). This template could be provided in a national policy statement under the Resource Management Act 1991 and could ensure an integrated holistic view that focuses on the sustainable use of resources at the regional level. Such an approach could result in a series of comparable regional State of the Environment reports that could be used at the national level if required.

In addition to a nationally required and regionally co-ordinated monitoring system, the different nature of the regions means that monitoring will have to address particular environmental problems. For example, the problem of spray drift in orchards is confined to particular regions.

There are thus two categories of monitoring requirements that could be carried out by both central government agencies and local authorities:

- *a national template to co-ordinate monitoring that is carried out at the regional level,*

- *a regional monitoring programme that focuses on the current or potential environmental problems specific to the region.*

These two monitoring programmes can and should be integrated where possible.

2.6 Requirements for integrated monitoring

In order that integrated monitoring is carried out by local authorities at the regional level, there is a need for the following steps to be taken.

1. Change of focus

In addition to focusing on resource problems, there is a need to look at the environment in a more holistic manner and to focus on the sustainable use of resources.

2. Clear objectives

by two different agencies there needs to be explicit coordination of a monitoring programme so that the state of the whole resource is taken into account. A change of management agency at an administrative boundary, for example, should not affect the overall objectives of managing and monitoring the resource.

3. *National template*
National guidelines produced by the Ministry for the Environment are needed that:

(a) require monitoring at the regional level (perhaps by requiring an annual assessment of the regional state of the environment),

(b) guide the direction of monitoring in the various agencies to avoid gaps and overlaps and to promote efficiency in collection, storage, access and processing,

(c) oversee the quality of information produced by monitoring programmes, co-ordinate its collation nationally and alert the appropriate agencies to the need to modify management.

4. *Resource inventory*
An inventory of the natural resources in each region is needed along with a list of human activities that might compromise the quality and/or quantity of the resources. The creation of a framework to guide this process may be appropriate.

5. *Resource management indicators*
Monitoring the state of a resource will involve the repeated measurement of particular environmental and social variables. From these, the careful selection of resource management indicators will allow policy makers and the public to focus on environmental policies and the state of the resource without needing to peruse all the environmental and social variables that have been measured.

CHAPTER 3

Prediction of major changes in ecosystems

How can we use an integrated monitoring system to predict changes in ecosystems?

Most existing monitoring systems were not designed for "early warning". Some of the major environmental problems in the world today were therefore not anticipated early enough to allow preventative action to be taken. Increasing technological development makes it likely that unexpected environmental effects will occur.

The cumulative environmental and social effects of human activity at all spatial scales is of concern when we consider the sustainable use of resources. "Most of the best known ecological problems such as disappearing forests, acid rain damage, the thinning ozone layer, and changing global climates, are the cumulative result of expanding economic activities around the world " (Rees, 1988, p.284).

Cumulative impacts result from the additive or synergistic effects of numerous incremental actions. One example of these impacts is termed chemical time bombs i.e. the gradual accumulation and sudden release of harmful man-made chemicals into the environment. These occur with changes in land use and climate and the continued accumulation of toxic materials in soils and sediments, despite the decreasing emissions of these substances. For example there is a trend of increasing mercury content in fish in Swedish lakes, even though Swedish industries have significantly decreased mercury emissions in the last 20 years (Hakanson *et al.* in Stigliani, 1988).

Rees (1988) suggests that society often takes little notice of gradual changes in environmental parameters until it is too-late for effective mitigative action. Since often the homeostasis and resilience of ecosystems "absorb" incremental impacts for long periods without obvious ill effect, a false sense of security is produced that all is well when, in fact, we are being led into an ecological trap.

A first comprehensive attempt to quantify the effects of acid air pollution on the forests in Europe predicts early warnings about forest conditions in the future. It has been suggested that pollution damage to forests alone costs Europe at least US$30 billion a year. Additional costs in terms of adverse effects on human health from leaching of heavy metals into ground water and widespread damage to buildings are probably impossible to calculate. Evidence is mounting that it might be cheaper to clean up the air pollution than to continue to repair the damage (Clark, 1990).

Closer to home, geologists warned about the erosion problems of the East Cape earlier this century. In 1896 Sir James Hector warned that the elimination of forest cover on the East Cape would result in widespread erosion. His warning, like many since, went unheeded (Graeme, 1990).

The spread of wilding trees in the New Zealand mountain lands has been termed "a time bomb" waiting to explode (Mason, 1990). The current problem of rabbits and *Hieracium* in the dry tussock grasslands in the South Island is an example of an explosion that has already occurred and still there is:

> *"no agreement or consistency of approach ..... on early warning indicators for monitoring of land condition"* (Hughes *et al.*, 1991).

Kelly and Harwell (1990) discuss the problems involved in characterising ecosystems and predicting ecosystem responses to disturbances. They use the analogy of characterising human health and point out that, because of lack of knowledge, the health of ecosystems is less easily defined and their dynamics are less manageable. They suggest that "suites of indicators" can be used to characterise an ecosystem, with each relating to particular parts of the ecosystem although no one group of indicators represents adequately the entire ecosystem.

In order to predict ecosystem change we need to understand different scales of time and space. Holling (1986) points out that ecosystems cover scales from a few square metres to a few thousand square kilometres and from a few years to a few hundred years. External abiotic events have a major impact on ecosystems but are mediated through strong biological interactions within ecosystems. The spatial scale, therefore, is determined by the dispersal distance of the most mobile of the key biological variables while the time span, of up to a few hundred years, is set by the longest-lived or slowest-acting key biological variables (Holling, 1986). Holling gives an example of the spruce budworm, which attacks and kills balsam fir in North America. The minimum spatial scale for analysis is about 70 000 km^2 and the slowest variable is the life time of trees which requires a time scale for analysis of about 200 years. Stigliani (1988) provides an example of lake acidification in New York State. The slowest variable that should have been monitored 30 years beforehand to predict the acidification was the buffering capacity of the watershed soil. Other variables such as the pH of the lake water or sulphur emissions would not have predicted the changes in the lake.

3.1 Approaches to predictive monitoring

If sustainable development of the biosphere is a long-term goal, monitoring must become an integral component (Izrael and Munn, 1986). We need appropriate indicators that something is going wrong in sufficient time to make policy decisions to correct the damage. In order to develop these indicators, Izrael and Munn (1986) recommend that we need to:

- look at historical analogies to identify the indicators that might have been used,
- focus on early warnings of ecological shifts, and
- identify, quantify and monitor the balance between positive and negative feedback mechanisms in bio-geophysical, ecological and socio-economic systems.

Several approaches can be used to address these recommendations and these may interact with each other.

3.1.1 Long-term ecological monitoring

Long-term ecological research and monitoring have been discussed in Section 2.2. Monitoring can provide base-line data and trends in environmental variables over a long period to establish an understanding of how ecosystems might change in the future given particular environmental conditions such as climate or certain types of management. Care must be taken in the interpretation of the data because to detect true changes in the environment it is necessary to distinguish between "natural background oscillation" and changes due to catastrophic events or human-induced causes.

In the absence of long-term ecological monitoring, it is sometimes possible to put together a picture of previous ecosystems using historical evidence, such as tree rings and lake sediments (Strayer *et al.*, 1986), and climate data and flow records that were available long before any monitoring programmes were initiated (K.F. O'Connor, Centre for Resource Management, pers. comm.). Part of the problem of assembling data from past sporadic monitoring is the use of different methods of data collection and analysis. An example of this situation was found during the compilation of the inventory of New Zealand lakes where diverse sources of data were brought together for comparison (Livingston *et al.*, 1986).

By substituting space for time, it may be possible to understand long-term ecological processes in short-term studies. For example, to study plant succession in old fields, it may be possible to study fields abandoned one, two, five, 10 and 30 years ago and assume that the succession among the plant communities at the various sites when combined is the same as the succession in plant communities that occurs in a single site for the first 30 years after abandonment (Strayer *et al.*, 1986). This process assumes an even, consistent environment with the absence of sudden, drastic change due to spasmodic climatic or other events.

3.1.2 *The use of models*

The use of models to predict long-term behaviour of ecosystems is not expected to provide a detailed picture of change because of limited knowledge of the functioning of real ecosystems. However, models are useful in the design, execution and interpretation of long-term studies (Strayer *et al.*, 1986).

Considerable research is underway at present to predict climate change. The role of the ocean in determining climate is often underestimated but understanding and predicting ocean behaviour can lead to an understanding and prediction of climate (Stewart, 1990). The role of monitoring and modelling becomes fundamental to this understanding. In addition there is a need to establish a link between climate change and sea level rise (Pugh, 1990), which requires large-scale monitoring and modelling systems.

Models are useful for anticipating an irreversible trend in an environmental variable but predictions will be rather uncertain because the models are calibrated on current or historical data. In addition, the **early** stages of a trend will be hard to detect because of the great natural variability in environmental conditions (Izrael and Munn, 1986). Izrael and Munn consider it important to try to optimise early warning monitoring systems, such as by carefully selecting indicators, monitoring sites and averaging times.

Izrael and Munn (1986) point out that discontinuities such as flip-flops and overshoots, that are familiar to engineers and physical scientists, where a system changes rapidly to a new and very different state or even collapses, have been applied to ecological and socio-economic systems in recent years. Models that simulate random behaviour can be used to identify key elements of an early warning monitoring system. To compare several management strategies, certain indicators of the ecosystem are monitored in the model to provide the earliest possible signs as to whether or not a particular management strategy is working (Izrael and Munn, 1986).

3.1.3 *Mass balance*

Another method for predicting environmental change is a materials-balance approach that tracks the flows of hazardous chemicals through the industrial economy from production and processing to end uses and disposal. Estimates of the accumulation of trace substances can often be more accurately obtained by this method than by standard monitoring because of the focus on particular hazardous chemicals and their breakdown products. However, an inventory of relevant historical data supplemented by indirect indicators of past conditions is needed for this approach (Ayres and Rod, 1986; Stigliani *et al.*, 1989).

Detailed book keeping of the sources and flow of selected toxic materials needs to be maintained. Then models can be constructed to generate a range of possible scenarios for materials use that would complement the numerous existing scenarios for population and energy use (Stigliani *et al.*, 1989).

This approach can be used to track the flow of contaminants through ecosystems. For example, in a pine forest ecosystem sulphur and heavy metals can be traced through the needles, litter, upper soil components and earthworms (Breymeyer, 1981). In aquatic ecosystems, heavy metals from industry, storm water runoff and sewage discharge can be traced from their source through the water column to the sediments and biota (Smith, 1986).

3.1.4 Change in capacity

A change in capacity or carrying capacity demonstrated by an ecosystem can act as an early warning signal of environmental change. An understanding of carrying capacity provides a functional definition of sustainable development. Ecologically, any development or ecological activity that does not exceed carrying capacity of the region is sustainable (Rees, 1988).

Rees (1988) defines carrying capacity for most animal species as:

> *"the maximum population that can be supported indefinitely in a given habitat without permanently impairing the productivity of the ecosystem(s) upon which that population is dependent"* (p.258).

For human society:

> *"regional carrying capacity can be defined as the maximum rate of resource consumption and waste discharge that can be sustained indefinitely in a defined region without progressively impairing bio-productivity and ecological integrity"* (Rees, 1988, p.258).

This definition only applies to renewable resources such as water, agriculture and forestry. Dividing the total ecosystem capacity by mean per capita rates of resource consumption and waste production would provide the maximum size of the human population that can be supported (Rees, 1988). By monitoring carrying capacity, early warning of environmental damage may be possible.

Devlin and O'Connor (1989) describe carrying capacity in terms of recreation management:

"the impact of recreationists will continue to be an active and increasing threat to preservation unless the responsibility for making judgements on use levels belongs within a comprehensive framework which includes all relevant biophysical, social and managerial conditions" (p.181).

Stigliani (1988) discusses buffering capacity, adsorption capacity and redox potential of soils and sediments as an inter-connected system for regulating the retention and release of chemical pollutants. These three capacities, along with toxic chemicals accumulation, are termed the "critical environmental indicators" (CEI) and serve as the goals of the environmental assessment. However, it is also preferable, where possible, to identify not only the primary linkages between development activities and environmental effects but also secondary linkages i.e. an activity may affect a given CEI through an intermediate influence on another indicator. For example, a source of pollution may act on the environment through an intermediate step that may involve depleting some capacity because another pollutant accumulates. This depletion can be detected by monitoring this intermediate step which is a slowly changing variable.

Stigliani (1988) illustrates this delay between cause and effect using two examples (Figure 3.1). In the top diagram, lake acidification is the result of burning fossil fuels which causes a depletion in the soil's buffering capacity and subsequent lake acidification. Here it is the buffering capacity that needs to be monitored as an early warning indicator of ecosystem change. In discussing this example, Stigliani (1988) points out that monitoring other indicators, such as the pH of the lake water or SO_2 emissions, would not have predicted lake acidification. Only by monitoring the buffering capacity of the soil, which is a slow variable showing only minor changes every year, could lake acidification have been predicted. In Figure 3.1(b), draining wetlands will increase the redox potential which will cause a depletion in the soil's buffering capacity and subsequent lake acidification. Here we have a more complex linkage between cause and effect with two indicators that need to be monitored to predict the indirect effect caused by the drainage of a wetland.

These examples illustrate the importance of choosing the right indicators to measure when designing a predictive monitoring programme.

3.2 Early warning indicators

For monitoring systems to be adequate as early warning of environmental change, ecological indicators must be used along with socio-economic indicators so that policy makers can assess the state of the environment in conjunction with socio-economic quality. Opschoor (1989) suggests that indicators of sustainability can be broad enough to reflect both the environmental impacts of economic activities and environmental management, such as pollutants, resource inputs and spatial claims, and the change in the state of the environment, such as stocks of environmental assets, ambient environmental quality and biological diversity. Stigliani *et al.* (1989) recommend that the selection of early warning indicators should be based on well-formulated models of the impacts of socio-economic stresses on the environment.

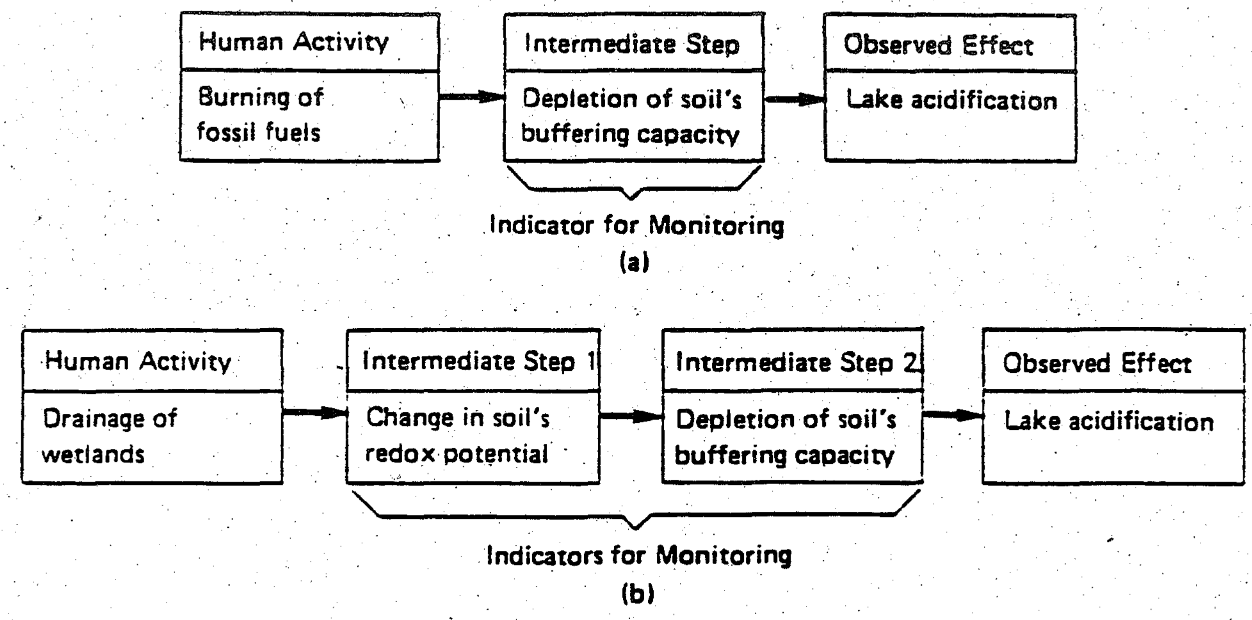

Figure 3.1 (a) Simple linkages between cause and effect for acid deposition and lake acidification.
(b) More complex linkages for drainage of wetlands and lake acidification.

Table 3.1 shows some potential early warning indicators based on suggestions by Stigliani *et al.* (1989), Huffman (1987) and Holling (1986). These early warning indicators provide an overlap between indicators of environmental quality, such as those recommended by Ward (1990) for State of the Environment reporting, and indicators of sustainability as discussed by Opschoor (1989), Shearer (1989) and Wright (1990).,

Braat (1991) distinguishes two types of indicators of sustainability. Predictive indicators:

> *"provide direct information about the future state and development of relevant socioeconomic and environmental variables. This information constitutes the basis for anticipatory planning and management. The predictive power is based on mathematical models of the man-environment system"* (p.57).

Retrospective indicators include the traditional policy evaluation and historical trend indicators.

"They provide information about the effectiveness of existing policies or about autonomous developments, respectively. From these indicators decision-makers may learn and improve policy effectiveness. In this way [they] may provide indirect information about future sustainability. They are usually quantified by a combination of measured data and reference values (e.g., historical situations, economic targets, health standards)" (p.58).

For effective indicators of sustainability, Braat (1991) suggests that both predictive and retrospective indicators are needed. In this way policy making is not locked in a "trial-error-evaluation-new trial cycle" and yet scientifically reliable information is obtained that is not based on risky predictive methods. By distributing resources over both predictive and retrospective strategies it is hoped that modelling will benefit from increased data collection and evaluation of policy effectiveness.

Table 3.1 Early warning indicators of ecosystem change after Stigliani *et al.* (1989), Huffman (1987) and Holling (1986).

Energy	* percentage use of each type of energy system * rate of consumption
Natural resources	* loss of habitats * competition for food or space * patchiness and soil composition for terrestrial ecosystems * nutrient losses and gains * buffering capacities of soils and lakes * oxygen depletion in lakes and seas * accumulation of toxic substances * water quantity available * water consumption by main users * water consumption per $1000 of GNP * output of production per unit of resources used * imports and exports of natural resources and products * changes in allocation among different land uses * rate of development of resort and retirement areas
Agriculture, forestry, fisheries	* quantity and types of harvests * changes in soil quality (depth, organic matter content, nutrient content, buffering capacity, slope steepness etc.) * accumulation of toxic substances * fertiliser, pesticide and herbicide sales * imports and exports of primary and processed foods * changes in farm incomes, debt/equity ratios, employment rates etc. * changes in self-satisfaction of farmers and farm workers * migration to cities * changes in the ability of the system to withstand shocks such as droughts, floods, pest outbreaks etc.
Pollution	* technological developments and assessments of their potential * installation of air pollution control equipment * construction of sewage treatment plants * installation of recycling systems * community recycling programmes * funds expended on pollution control equipment

CHAPTER 4

Traditional Maori monitoring practices

In this chapter traditional Maori monitoring and options for incorporating this knowledge into a national monitoring system are discussed.

4.1 The past

Traditionally, Maori people identified strongly with the natural world around them. They were entirely dependent on the environment for survival and had a profound knowledge of the resources that it provided.

> *"On an intellectual and emotional level, their relationship with the environment was equally close. It shaped the very processes of thought; it led to the development of ideas explaining the origin and nature of the world; and since affinities were felt to exist between all living things, it was a source of images that were applied to human beings (p.15).*

> *"Their closeness to nature and the immediacy of their dependence upon it, their intimate and profound knowledge of plants, animals and landscape, led to a view of the world which recognised the tapu, the sacredness, of other life forms and the landscape itself. By seeing themselves in the natural world and thus personifying all aspects of the environment, they acquired a fellow-feeling for the life forms and other entities that surrounded them, and they saw a kinship between all things"* (p.216) (Orbell, 1985).

Despite the exploitation of resources by the early Maori settlers, by the seventeenth century an elaborate set of rules, restrictions and guidelines existed for the control and use of resources enforced by concepts such as *tapu* and *rahui* (Patrick, 1987). Everything in nature, living and non-living, has *mauri* (the physical life principle) and is descended from common ancestors, so all elements of the natural world possess life, a universal living spirit. Preservation of the mauri was extremely important and there was a constant risk of limiting or affecting it by every day use of the environment. To prevent this degradation, a set of rules governing conduct and behaviour consistent with spiritual tribal beliefs had to be followed (Gray, 1990). These rules exerted a real influence over the management of resources, fostering respect and fear.

Gray (1990) describes how Maori values are actively expressed through human behaviour and/or rituals (Figure 4.1). The ethics, rituals, institutions, laws and the concepts of tapu and rahui are carried out in the *kawa* or operational procedures and practices.

4.1.1 The concept of rahui

Marsden (1988) explains that the concept of rahui fulfilled two main functions:

1. It was imposed on the occasion of drowning and/or death for about a month. This was an appropriate way of paying respect and conveying sympathy to the whanau and family of the deceased, and allowed time for the tapu associated with the death to be dispersed naturally by the cleansing powers of the natural elements.

2. It was imposed to conserve or replenish a resource, such as fish, birds, berries or timber, by banning people from using a specified area such as a river, lake, harbour or forest. Monitoring determined when the resource had regenerated sufficiently and the tapu was lifted with the appropriate kawa.

Under a rahui, birds, rats and fish were protected for much of the year to ensure that breeding was not disturbed, the numbers were not unduly depleted and they were caught only in the best condition. For each type of fish, there was knowledge of its habits, the proper times and places for catching it and the right ways of doing so (Orbell, 1985). It was forbidden to gut fish or to dispose of small fish, excess bait or rubbish in the open sea because waste was thought to attract predators and upset the natural balance of the ecosystem in a particular area (Waitangi Tribunal, 1988). Nets, lines, sacks or baskets must be lifted and never dragged on the sea bed or over shellfish beds because it may damage the fishing ground and hence the habitat of the fish and shellfish species (Waitangi Tribunal, 1988). The fish in a river may be protected by a rahui while people were still allowed to drink the water and use canoes in the river (Best, 1977).

Families and tribal groups only hunted and fished in their own territories for there was trouble if they were caught trespassing (Orbell, 1985). A rahui was used when a crop was attacked by caterpillars until the pests were destroyed and cultivation could resume (Best, 1977). The fruit of the *tutu* shrub (*Coriaria ruscifolia*) was highly valued and the shrub was often placed under a rahui by its principal owner to protect it from destruction during the fruiting season (Best, 1977). A rahui had to be lifted by the tohuka or mediator in a ceremony that might also be used to ensure the success of a hunt or other undertaking.

4.1.2 The concept of mana

The concept of *mana* embodies the spiritual power and authority delegated by the *atua* (gods) to chosen representatives to perform their wishes in the natural world. The drive to maintain and increase mana was essential to the functioning of the whole physical, social and spiritual system (Gray, 1990). Gray (1990) outlines three components of the mana of Maori people:

Mana kai	The provision of food and materials necessary for the sustenance and survival of the family and tribe, and the production of surplus. Surplus food meant the ability to increase personal and tribal mana by providing hospitality for visitors in the form of feasts. Each hapu had its own traditional specialities of *kai moana* (sea food) and *kai awa* (river food). Surplus food could also be used for trade.
Mana whenua	This concept is central to the Maori world view of the environment. Land is the source from which all knowledge, whakapapa, history, food and resources are derived. Land was also a reminder of the kinship of people with the Earth mother, Papatuanuku.
Mana takata	This concept is the link between a person's genealogical origins and the primal parents. Mana takata derives its meaning and purpose because of land (mana whenua) and resources (mana kai). Without these two, mana takata cannot exist.

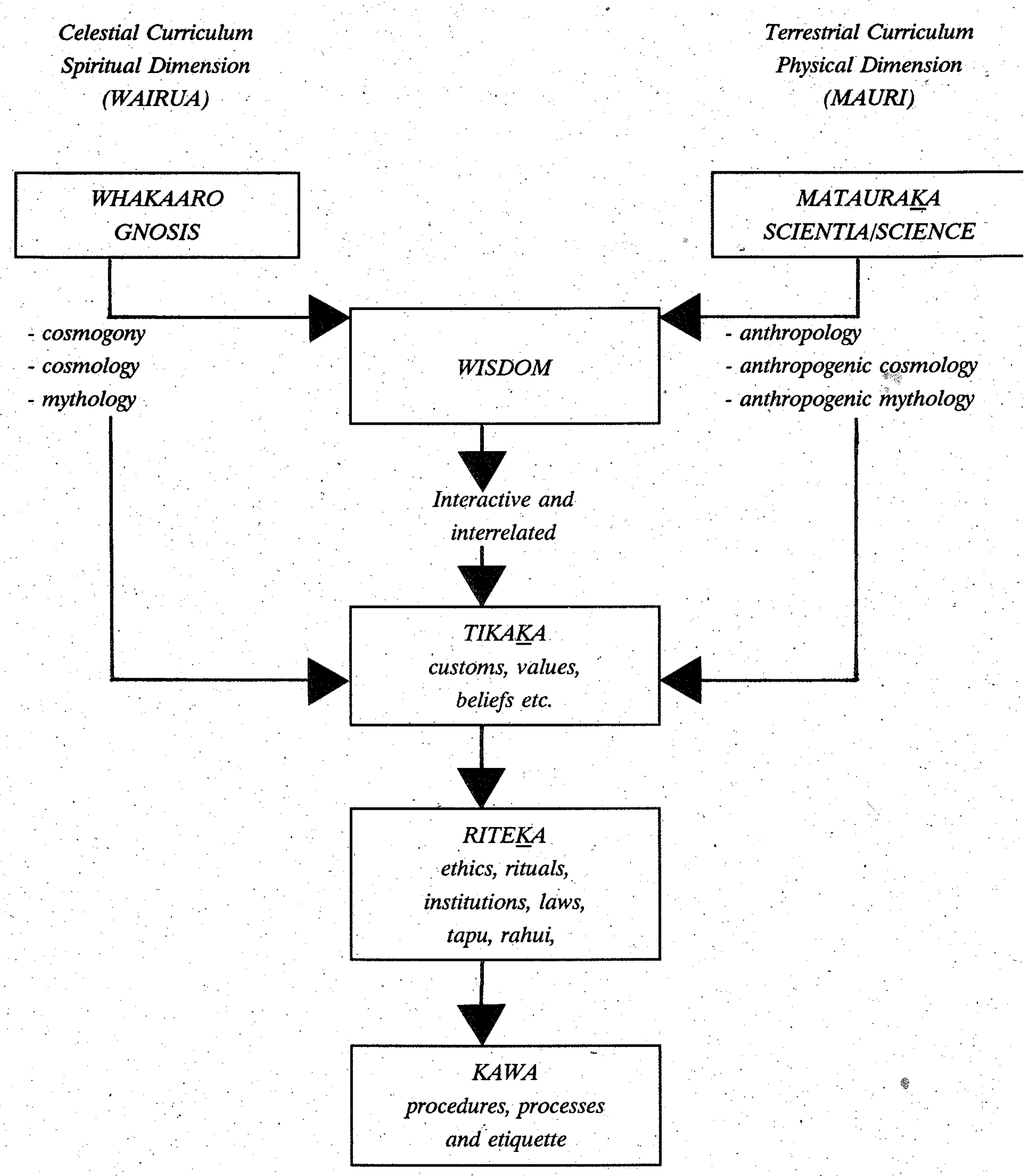

Figure 4.1 Ka Tikaka Maori - The matrix of wisdom and knowledge (after Gray, 1990).

4.1.3 Concepts of resource management

Concepts of resource management were demonstrated in the Maori ability to manage their resources on a seasonal basis. Monitoring was an essential part of this process. Indicators of the natural changes and health of components of the environment were part of Maori consciousness because it was in their interest to be aware of the state of their environment in order to safeguard their survival. There is evidence of sophisticated management techniques for increasing and decreasing shellfish populations to provide an optimal product, and genetically superior strains were recognised and transplanted to other areas. The breeding cycles, feeding habits and migration times of freshwater and seawater species were also well understood with regard to harvesting times (Palmer and Goodall, 1988). Selective fishing took place so that only particular species were taken at any one time and the balance of species was maintained. Fishing grounds that showed signs of depletion were retired from use (Waitangi Tribunal, 1988). The juveniles of some species, such as paua and crayfish, were taken to maintain the larger breeding stock (Sage, 1990).

Monitoring may not have been a specific task but part of every day activity. Best (1977) records that Maori people closely observed plants and the stars in order to predict whether the coming season would be one of plenty or the reverse. In particular, flowering trees were scanned for signs of a good or bad season and the flowering and fruiting of many plants helped to denote seasons and the time for annual tasks. When trees start to blossom on their lower branches first, then a *tau ruru*, a warm and bountiful season, will follow. If they blossom first at the top, a *tau matao*, a cold unproductive season, follows. Birds were believed to understand the coming season before people for if they were seen flying upward in flocks, then swooping down with extended, motionless wings followed by gambolling on high and then alighting, a fruitful season would follow.

The Waitangi Tribunal were told how the Kai Tahu people led a mobile life. In spring they dispersed to where their resources were seasonally abundant. Here they preserved food which they took back to their more long-term settlements in autumn (Waitangi Tribunal Report, 1991). Best (1977) describes the seasonal bird hunting that took place around May. From about March, responsible and capable bushmen were allowed to search the forest examining the bird-food supply. If the food crop was good, the supply of birds would be good. There were two ways of recognising the correct time to begin taking any bird species: firstly, the ripening of certain berries, the fall of deciduous leaves, the dying away of certain annuals or the flowering of certain plants; secondly, some birds were snared to make sure that they were ready to be eaten. During the bird-hunting season the forest was under tapu so that no trespasser could cause the birds to leave the area.

As Patrick (1986) points out, it is difficult to consider the traditional Maori lifestyle as anything other than a basic conservation ethic.

4.2 The present

Today, contemporary science and traditional techniques are carried out by Maori people but they are not necessarily linked by the relationships shown in Figure 4.1. There is a renaissance in terms of Maori sciences, *tikaka* (values), *riteka* (ethics) and *kawa* (practices). These concepts are part of a strong core of information about traditional and contemporary processes. That information will be used to manage natural resources in general and management must be monitored by a process that is consistent with *kaupapa Maori* (essential things Maori) (M. Gray, Centre for Resource Management, pers. comm.).

> *"Conserving Maori realities is the act of preserving Maori values and beliefs. Values are the practice of belief. For example, if you believe that the earth is your mother, then you will treat the earth accordingly"* (Gray, 1990).

Many Maori still identify strongly with the natural world. Traditional lifestyles and practices are common today among those cognisant of the Maori way of life. The kaitiaki or guardians watch the environment for signs from the weather, the plants etc. so that there is understanding about natural events and so that predictions can be made.

However, the current problems over Maori ownership or guardianship of land and resources have meant that little attention is given by management authorities to the traditional way of conserving resources. For example, the concept of maintaining tribal mana is still very important to Maori people. The provision of hospitality to guests in the form of food is still one of the most important traditional sources of tribal mana and, with the loss of ownership and guardianship, these resources have been put at risk. Another example is given by the Muriwhenua people (Waitangi Tribunal, 1988) who speak of the bountiful supplies of fish in the past. They still monitor the amounts of seafood taken from their traditional fishing grounds so that there will always be plenty, but the elders can no longer count or control the losses from "outsider raiding" by those who do not live in the local community. Fisheries legislation has interfered with Kai Tahu's traditional fishing practices: fines are imposed for catching trout while fishing for eels; access to traditional fishing areas at traditional times has been restricted; and the traditional sharing of any catch, particularly with the elderly, is limited by the restrictions of total allowable catch (Palmer and Goodall, 1988).

4.3 Incorporating traditional monitoring

Those who still live in the traditional way with Maori spiritual values and knowledge may inform their kaitiaki or tohuka if something is wrong in the natural world and it will be dealt with by traditional methods. Those who have adopted the Pakeha way, however, would probably inform the Department of Conservation or local authorities if they noticed that something was wrong and the response would probably be of a different type.

Traditional Maori may receive indications that something is wrong before the local authorities have obtained this information. For example, monitoring of mussel beds on the Te Atiawa reefs identified the fragile shells of mussels in an area where the shellfish were under stress, so that the mussels could no longer be used (Waitangi Tribunal, 1983). Frequently, early warning of an environmental problem can result in quicker and more effective management. Management agencies may therefore perform their tasks more effectively by learning from and participating with Maori in the management of resources.

This co-operation in resource management may not be easy until the issues of ownership and management of resources are settled. The role of the Maori Advisory Committees is to give advice to the local authorities on matters of concern to the takata whenua - "to provide for consultation and discussion between Tangata Whenua and regional councils and territorial authorities" (Amendment No. 8 to Local Government Act (1974) Section 114W). However, the recommendations of any Maori Advisory Committee are not binding upon regional councils and territorial authorities.

Several regional councils have established iwi partnership committees but the effectiveness of these in terms of improved management of natural resources through the incorporation of traditional Maori knowledge is questionable. Canterbury Regional Council has facilitated the preparation of Kai Tahu's Resource Management Strategy for the Canterbury Region (Tau *et al.*, 1990). This document states Kai Tahu beliefs and values that need to be taken into account when the Regional Council is preparing a regional policy statement and regional plans under the Resource Management Act 1991. This type of document could provide an important and relevant context for incorporation of traditional Maori knowledge of the environment into predominantly Pakeha approaches to, and institutions for, management.

Under Sections 6(e) and 7(a) of the Resource Management Act 1991 the relationship of Maori with the environment is recognised as a matter of national importance and must be taken into account when managing, developing and protecting natural and physical resources. Under Sections 61(2)(a)(ii), 66(2)(c)(ii) and 74(2)(b)(ii) local authorities are required to have regard to any iwi management document when preparing regional policy statements and plans. The Act clearly expects consultation between takata whenua and local authorities to take place. According to Whareaitu (1991) consultation with takata whenua is appropriate when there is a legal obligation to do so, when it is fair and courteous and when it feels right. However, it should not be carried out just for the sake of being seen to do so. Honest intentions are required. Ritchie (University of Waikato, pers. comm.) considers that **recommendations** for consultation with Maori on environmental monitoring are not sufficient; they have been tried and have failed. Maori need to be empowered if they are to have an input to regional policy statements and plans. This is now possible under the new Act.

Even if particular natural resources are no longer essential for the physical survival of contemporary society, there must be a means of communicating observed changes in the environment to add to the pool of monitoring information. Those Maori people who are still "in touch with the natural world" need to be empowered to inform the monitoring agencies when they are aware of any environmental change, particularly when it may be detrimental to the health of people or to a particular resource. Mutual understanding of indicators of environmental health, such as the kaitiaki tuna which prevents the depletion of stock (M. Gray, Centre for Resource Management, pers. comm.), is an essential part of this process.

There is a need to resolve those management strategies that are not compatible with traditional Maori management, such as the taking of large breeding individuals while Maori people retain such individuals to replenish the stock and take only small individuals (M. Gray, pers. comm.). Another example is the length of the whitebait fishing season in the Ashley River, North Canterbury, which Rakiihia Tau, Deputy Chairperson of the Kai Tahu Maori Trust Board, considers is too long and should not be operational in August when spawning whitebait are still coming down the river. In late November, breeding inaka are moving downstream to spawn and fishing should be stopped before this time (Sage, 1990).

It was pointed out by McRae *et al.* (1989) that the aims of Maori conservation and monitoring methods, as we understand them so far, do not conflict with environmental monitoring when this relates to sustaining the well-being of natural resources. The main difficulty will be the establishment of monitoring methods, indicators and institutional arrangements that recognise both Maori and European ways of doing things. A formal relationship needs to be established between central and regional government monitoring agencies and Maori people.

In order to develop this relationship, it is recommended that:

1. Maori need to be empowered to make an input into monitoring programmes. This will require people with ability and knowledge of the natural world and an assurance of funding for any work undertaken. A training programme may also be needed to enable Maori to understand European-type monitoring programmes.

2. Iwi should be encouraged to develop and update management plans.

CHAPTER 5

Conclusions

In order to focus on sustainable development in New Zealand, there is a need to consider the environment in a more holistic manner and to use integrated environmental monitoring to reflect changes in the state of the environment. Integrated monitoring must be guided by a national framework that is implemented at the regional level. This will allow a focus on catchment monitoring so that changes in ecosystems and the effect of human activities on these ecosystems can be more easily monitored and the results co-ordinated locally. For regions to be comparable, similar approaches and methodology must be used. National guidelines could be laid down by the Ministry for the Environment and incorporated in national policy statements under the Resource Management Act 1991 so that regions are required to undertake nationally co-ordinated monitoring to provide a comparable national overview. This national template must also guide the direction of monitoring to avoid gaps and overlaps and to promote efficiency in data collection and processing. National co-ordination and collation of the regional monitoring programmes is needed to oversee the quality of information and advise agencies of the need to modify management. The regional monitoring could be carried out by local authorities working with the Department of Conservation, Department of Scientific and Industrial Research, Forest Research Institute or new Crown Research Institutes, and other agencies as applicable.

Local authorities and central government agencies will continue to monitor at the regional level for current or potential problems in the region and for compliance. Details of some of this type of monitoring are covered in another report (Ward, 1991). However, some regional monitoring will undoubtedly contribute to the national "picture".

Monitoring to predict major change at the ecosystem level will not happen under most existing monitoring systems. The design of an early warning monitoring system requires a sound understanding of environmental and socio-economic processes. The choice of indicators needs great care, and experts in their respective fields who can identify the intermediate steps between cause and effect need to be involved. The system needs a national framework, perhaps put forward by the Ministry for the Environment with expert inputs from the Department of Scientific and Industrial Research, Department of Conservation, Ministry of Agriculture and Fisheries, Ministry of Forestry etc. Legislation would be required so that the appropriate agencies carry out monitoring for early warning. Some approaches to predictive monitoring discussed in this paper, such as long-term ecological monitoring, are already being carried out in New Zealand to some extent and these could be formally incorporated into a national framework by the Ministry for the

Environment and extended where necessary. Central government agencies should have sufficient expertise to interpret the data and be aware of potential critical change.

There also needs to be a process through which early warning signals are channelled, co-ordinated and passed on to decision-making bodies. Too often, early warning of potential problems, such as warnings of severe erosion in New Zealand, have gone unheeded until the damage is done.

An holistic approach to environmental monitoring cannot ignore social and cultural values. Traditional monitoring carried out by Maori people was an essential part of survival in New Zealand. They developed an in-depth understanding of the environment upon which they depended. Their traditional view of the environment reflects an integrated approach that needs to be incorporated into a national or regional monitoring system by involving Maori people in planning and decision making at the regional level. The Resource Management Act 1991 clearly expects consultation to occur between the takata whenua and local authorities. Maori people with traditional knowledge of the environment and an understanding of traditional environmental indicators need to be empowered to contribute to a bicultural monitoring system. Assurance of funding for any work undertaken and the provision of training programmes may be prerequisites for Maori input into this monitoring process.

References

Ayres, R.U. and Rod, S.R. 1986. Patterns of pollution in the Hudson-Raritan basin. *Environment 28:* 14-20, 39-43.

Baines, J.T., Wright, J.C., Taylor, C.N., Leathers, K.L. and O'Fallon, C. 1988. The sustainability of natural and physical resources - interpreting the concept. *Studies in Resource Management No. 5.* Centre for Resource Management, Lincoln College.

Biggs, B.J.F., Duncan, M.J., Jowatt, I.G., Quinn, J.M., Hickey, C.W., Davies-Colley, R.J. and Close, M.E. 1990. Ecological characterisation, classification, and modelling of New Zealand rivers: an introduction and synthesis. *New Zealand Journal of Marine and Freshwater Research 24(3):* 277-304.

Bernes, C., Giege, B., Johansson, K. and Larsson, J.E. 1986. Design of an integrated monitoring programme in Sweden. *Environmental Monitoring and Assessment 6:* 113-126.

Best, E. 1977. *Forest lore of the Maori.* E.C. Keating, Government Printer, Wellington.

Braat, L. 1991. The predictive meaning of sustainability indicators. *In:* Kuik, O. and Verbruggen, H. (Eds) *In search of indicators of sustainable development.* Kluwer Academic Publishers, Dordrecht, The Netherlands. pp.57-70.

Braat, L.C., Brouwer, F.M., Gilbert, A., Hulzebos, E. and Hafkamp, W.A. 1987. Integrated modelling of renewable natural resources: the economic-ecological interface. *FAST Occasional papers, FOP 172.* Directorate for Science, Research and Development, Commission of the European Communities, Brussels.

Brenneman, J. (Ed.) 1989. *Long-term ecological research in the United States. A network of research sites 1989.* (5th edition). LTER Network Office, College of Forestry Resources AR-10, University of Washington, Seattle, WA 98195. 44p.

Breymeyer, A.I. 1981. Monitoring of the functioning of ecosystems. *Environmental Monitoring and Assessment 1:* 175-183.

Chapman, P.A. and Long, E.R. 1983. The use of bioassays as part of a comprehensive approach to marine pollution assessment. *Marine Pollution Bulletin 14(3):* 81-84.

Clark, M. 1990. The price of pollution. *IIASA Options (September)*: 4-8.

Cocklin, C. and Parker, S. 1990. Cumulative environmental change: concepts revisited and a case study. *Environmental Science Occasional Publication No. CEC-03.* University of Auckland.

Devlin, P.J. and O'Connor, K.F. 1989. Exploring relationships of recreation users, impacts and management. *In:* Proceedings of a symposium on environmental monitoring in New Zealand with emphasis on Protected Natural Areas, Dunedin 1988. Department of Conservation, Wellington. pp.178-187.

Graeme, B. 1990. East cape erosion. *Forest and Bird 21(4):* 36-39.

Gray, M.M. 1990. Nga taonga tapu Maori o te kohatu. Prized treasures from the traditional world of the Maori. Unpublished paper. Centre for Resource Management, Lincoln University.

Holling, C.S. 1986. The resilience of terrestrial ecosystems: local surprise and global change. *In:* Clark, W.C. and Munn, R.E. (Eds). *Sustainable development of the biosphere.* IIASA and Cambridge University Press. pp.292-320.

Huffman, T. 1987. Methods of assessing agricultural sustainability. *In:* Stokes, P. and Piekarz, D. (Eds). Ecological indicators of the state of the environment: Report of a workshop at the Institute for Environmental Studies, University of Toronto. Environment Canada. pp.45-48.

Hughes, H.R., Peterson, D.R., McEwen, M. and Leslie, D. 1991. Sustainable land use for the dry tussock grasslands in the South Island. Office of the Parliamentary Commissioner for the Environment, Wellington.

Izrael, Yu. A. and Munn, R.E. 1986. Monitoring the environment and renewable resources. *In:* Clark, W.C. and Munn, R.E. (Eds). *Sustainable development of the biosphere.* IIASA and Cambridge University Press. pp.360-377.

Kelly, J.R. and Harwell, M.A. 1990. Indicators of ecosystem recovery. *Environmental Management 14(5):* 527-545.

Knuth, B.A. and Neilsen, L.A. 1989. Social and institutional performance indicators for wildlife and fishery resource management systems. *Society and Natural Resources 2:* 329-344.

Livingston, M.E., Biggs, B.J. and Gifford, J.S. 1986. Inventory of New Zealand lakes. *Water and Soil Miscellaneous Publication Nos 80 and 81.* Ministry of Works and Development, Wellington.

LTER Network Office, 1989. 1990s Global change action plan utilizing a network of ecological research sites. Proceedings of a workshop held November 1989, Denver, Colorado. Long-Term Ecological Research Network Office, University of Washington, Seattle.

McEwen, W.M. (Ed.) 1987. Ecological regions and districts of New Zealand. New Zealand Biological Resources Centre. *Publication No. 5, Part 1.* Department of Conservation.

McRae, S., Taylor, N., Ward, J., Williams, T. and Woods, K. 1989. Environmental monitoring. Unpublished report for the Ministry for the Environment. Centre for Resource Management, Lincoln College.

McRae, T. and Smith, M. 1990. Reporting the state of the marine environment. Assessment, approach and indicators. Draft discussion paper. Strategies and Scientific Methods Division, Environment Canada.

Marsden, M. 1988. The natural world and natural resources: Maori value systems and perspectives. *Resource Management Law Reform Working Paper No. 29, Part A*. Ministry for the Environment, Wellington. pp.2-30.

Mason, C. 1990. Wilding trees. Paper presented to a wilding trees seminar. *Review 47:* 15-20.

Ministry for the Environment 1991. An introduction for local government to performance standards in resource management. Working draft for discussion purposes. Wellington.

OECD 1989. *Water resources management: integrated policies*. OECD, Paris.

Opschoor, J.B. 1989. Towards sustainable development: Environmental change and macro indicators. Draft paper. Institute of Environmental Studies, Free University, Amsterdam. 16p.

Orbell, M. 1985. *The natural world of the Maori*. Collins, Auckland.

Patrick, M. 1987. Maori values of soil and water. *Soil and Water,* Autumn: 22-30.

Palmer, D. and Goodall, A. 1988. Water resources and the Kai Tahu claim. *Resource Management Law Reform, Working Paper No. 29, Part B.* Ministry for the Environment, Wellington.

Pugh, D. 1990. Sea-level: change and challenge. *Nature and Resources 26(4):* 36-46.

Rees, W.E. 1988. A role for environmental assessment in achieving sustainable development. *Environmental Impact Assessment Review 8:* 273-291.

Sage, E. 1990. Mending the holes in the food baskets. *Terra Nova 1(1):* 27-29.

Shearer, W. 1989. How do we measure sustainability? *Development Forum:* 14.

Smith, D.G. 1986. Heavy metals in the New Zealand aquatic environment: a review. *Water and Soil Miscellaneous Publication No. 100.* 108p.

State of Washington Department of Ecology and U.S. Environmental Protection Agency. 1990. Toward 2010: an environmental action agenda. Department of Ecology, Olympia, WA 98504.

Stewart, R. 1990. The ocean and climate. *Nature and Resources 26(4):* 30-35.

Stigliani, W.M. 1988. Changes in valued "capacities" of soils and sediments as indicators of nonlinear and time-delayed environmental effects. *Environmental Monitoring and Assessment 10:* 245-307.

Stigliani, W.M., Brouwer, F.M., Munn, R.E., Shaw, R.W. and Antonovsky, M. 1989. Future environments for Europe: some implications of alternative paths. *The Science of the Total Environment 80:* 1-102.

Strayer, D., Glitzenstein, J.S., Jones, C.G., Kolasa, J., Likens, G.E., McDonnell, M.J., Parker, G.G. and Pickett, S.T.A. 1986. Long-term ecological studies: an illustrated account of their design, operation, and importance to ecology. *Occasional Publication of the Institute of Ecosystem Studies No. 2.* pp.1-22.

Swanson, F.J. and Sparks, R.E. 1990. Long-term ecological research and the invisible place. *Bioscience 40(7):* 502-508.

Tau, T.M., Goodall, A., Palmer, D. and Tau R. 1990. *Te Whakapapa Kaupapa: Ngai Tahu Resource Management Strategy for the Canterbury Region.* Aoraki Press, Wellington.

Waitangi Tribunal, 1983. Report findings and recommendations of the Waitangi Tribunal on an application by Aila Taylor for and on behalf of Te Atiawa tribe in relation to fishing grounds in the Waitara District. Wai-6. Waitangi Tribunal, Department of Justice, Wellington.

Waitangi Tribunal, 1988. Report of the Waitangi Tribunal on the Muriwhenua claim. Wai-22. Waitangi Tribunal, Department of Justice, Wellington.

Waitangi Tribunal, 1991. Report of the Waitangi Tribunal on the Ngai Tahu claim. Wai-27. Brooker and Friend Ltd, Wellington.

Ward, J.C. 1990. Indicators for State of the Environment reporting. *Information Paper No. 21.* Centre for Resource Management, Lincoln University.

Ward, J.C. 1991. Integrated environmental monitoring at the regional level. Draft report for the Foundation for Research, Science and Technology, August 1991.

Whareaitu, T. 1991. Consultation with tangata whenua: a guide to assist local authorities in meeting the consultation requirements of the Resource Management Act 1991. Ministry for the Environment.

Wright, J.C. 1990. Natural resource accounting - an overview from a New Zealand perspective with special reference to the Norwegian experience. *Information Paper No. 22.* Centre for Resource Management, Lincoln University.